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The Upper Cretaceous ammonite *Pseudaspidoceras* Hyatt, 1903, in north-eastern Nigeria

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CONTENTS

SYNOPSIS. The following species of *Pseudaspidoceras* Hyatt occur in north-eastern Nigeria, from oldest to youngest: *P. pseudonodosoides* (Choffat), *P. footeanum* (Stoliczka), *P. paganum* Reyment and *P. flexuosum* Powell. *P. pseudonodosoides* is represented by paedomorphic populations. *P. flexuosum* marks the basal Turonian of the region. The remaining species are all of Late Cenomanian age. *P. pseudonodosoides* occurs in beds correlatable with the *Neocardioceras juddii* Zone in south-western New Mexico but the Nigerian sequence is expanded in comparison; no equivalents of the horizons with *P. footeanum* and *P.paganum* are known in the former region. The Nigerian material demonstrates the great potential of *Pseudaspidoceras* in detailed correlation over the Cenomanian-Turonian boundary. Below the beds with *Pseudaspidoceras*, specimens probably referrable to *Burroceras* Cobban, Hook & Kennedy occur.

INTRODUCTION

In recent years renewed attention has been paid to the Cenomanian-Turonian ammonite faunas of north-eastern Nigeria (Wozny & Kogbe 1983, Popoff *et al.* 1986, Meister 1989, Zaborski 1990, Courville *et al.* 1991, Courville, 1992). Early descriptions were provided by Woods (1911), Reyment (1954*a*, 1954*b*, 1955) and, especially, Barber (1957, 1960), but these works generally lacked information concerning the precise stratigraphical occurrences of the material involved. The impetus for fresh studies has largely been provided by the opening of the Ashaka Cement Company's quarry some 00 km north of the town of Gombe. Here, unusually for the region, large ammonite collections can be made within a clear stratigraphical context. Coupled with information gathered from scattered localities elsewhere in north-eastern Nigeria, notably the Pindiga stream section, data from Ashaka have enabled a regional ammonite biostratigraphy to be worked out (Zaborski 1990). North-eastern Nigeria is emerging as a region of key importance in understanding the ammonite succession across the Cenomanian-Turonian boundary. The expanded sequences are dominated by vascoceratid faunas, but also contain acanthoceratid ammonites of wider geographical distribution, allowing correlations to be made with zonal schemes from north-western Europe and North America. One of the genera having such value is *Pseudaspidoceras* Hyatt, 1903, which is represented by four species, in ascending stratigraphical order: *P. pseudonodosoides* (Choffat), *P. footeanum* (Stoliczka), *P. paganum* Reyment and *P. flexuosum* Powell. In addition, forms probably referrable to the closely related genus *Burroceras* Cobban, Hook & Kennedy, 1989 occur lower in the sequence. The purpose of this contribution is to document the Nigerian material and to highlight its stratigraphical value.

The Ashaka and Pindiga sections

Although *Pseudaspidoceras* occurs widely in north-eastern Nigeria, only at Ashaka and Pindiga have more than one species been collected in an observed stratigraphical sequence. The locations of these sections and other localities mentioned herein were shown by Zaborski (1990), while a general account of the geology of the region was given by Carter *et al*. (1963).

A continuous section made up of ammonite-bearing limestones and interbedded barren shales of Late Cenomanian and Early Turonian age is exposed at Ashaka (Fig. 1). The Pindiga stream section is discontinuous and partly subject to burial and re-exposure during the summer rains. Figure 1 shows those parts of the section that have been logged over the period 1986 to 1992.

The Ashaka section is as follows (see Fig. 1; numbers in parentheses are the equivalent horizons in Meister (1989):

Bed		Metres
	Alternating shales and sandstones, the latter glauconitic, feldspathic and calcite-cemented below, quartzose above and with a 15 cm shelly, sandy limestone towards the top	12·00
	Glauconitic, gypsum-bearing clay	0·10
X (34)	Pale grey, nodular limestone with clay and gypsum laminae. *Vascoceras harttii* (Hyatt), *V. obscurum* Barber, *Pseudotissotia nigeriensis* (Woods), *Eotissotia simplex* Barber	0·43
	Blue-grey shales with gypsum	0·27
W (34)	Yellow, nodular limestone with *Thalassinoides* burrows on upper surface. *Pseudotissotia nigeriensis*, *Eotissotia simplex*	0·08
	Blue-grey shales with gypsum	0·25
V (34)	Yellow, nodular limestone with gypsum. *Thalassinoides* burrows on upper surface. *Pseudotissotia nigeriensis*, *Eotissotia simplex*, *Wrightoceras munieri* (Pervinquière)	0·06
	Blue-grey shales with gypsum	2·45
U (32)	Greenish-grey nodular limestone, weathering to creamy yellow, with clay and gypsum stringers. *Vascoceras* sp., *Pseudotissotia nigeriensis*, *Eotissotia simplex*	0·30
	Blue-grey shales with gypsum	1·55
T2 (30)	Glauconitic, calcareous clay with black phosphate pebbles. *Pseudaspidoceras flexuosum* Powell, *Watinoceras* aff. *coloradoense* (Henderson), *Vascoceras proprium proprium* (Reyment), *V. obscurum* Barber, *Thomasites gongilensis* (Woods), *Pseudotissotia nigeriensis*, *Wrightoceras munieri* and *Choffaticeras* sp.	0·06
T1 (30)	Cream-brown limestone with *Pseudotissotia nigeriensis* and *Vascoceras proprium proprium* (30)	0·12
	Blue-grey shales with gypsum	0·24
S (28)	Cream-brown calcareous concretions, forming a continuous layer in places	0·07
	Dark grey to blue-grey shales	1·00
	Glauconitic, calcareous clay	0·08
R (26)	Hard, pale grey limestone. *Pseudaspidoceras paganum* Reyment, *Vascoceras proprium globosum* (Reyment), *Thomasites gongilensis*, *Pseudotissotia nigeriensis*	0·26
	Calcareous, glauconitic, shelly clay, with shale partings forming a more distinct shale unit up to 50 cm thick in some places	0·10
Q (24)	Massive, hard, grey-green limestone. *Vascoceras* sp., *Thomasites gongilensis*	0·33
	Dark grey shales with gypsum; a 1–4 cm horizon crowded with small thin-shelled bivalves, bone fragments and small phosphatic pebbles occurs 15 cm below the top in some places	1·40
P	Clay, with gypsum and scattered white calcareous nodules	0·03
	Dark grey shales with gypsum	1·40
O (21–22)	Hard, grey-green, nodular limestone in top 8–15 cm, rubbly limestone with shale partings below. *Pseudaspidoceras footeanum* (Stoliczka), *Vascoceras proprium costatum* (Reyment), *V. proprium globosum*, *V. bullatum* (Schneegans), *V. nigeriense* Woods, *V. cauvini* Chudeau, *Thomasites gongilensis*, ammonite gen. et sp. nov.	0·32
N (20)	Hard, grey, massive crystalline limestone	0·50
M (19)	Rubbly, impure limestone with shale partings. *Pseudaspidoceras pseudonodosoides* (Choffat), *Vascoceras* sp. nov. aff. *gamai* Choffat, *V. cauvini*	0·73
L (18)	Hard, pale cream-grey, massive limestone	0·45
K (17)	Rubbly, impure limestone with shale partings. *Pseudaspidoceras pseudonodosoides*, *Vascoceras* sp. nov. aff. *gamai*, *V. cauvini*	0·50
J (16)	Hard, grey limestone, cross-bedded in places	0·42
I (14–15)	Hard, grey limestone, cross-bedded in places	1·07
H (12–13)	Hard, grey limestone, cross-bedded in places. *Vascoceras cauvini*	0·85
G (11)	Massive, pale to dark grey limestone, passing laterally into bioturbated grey-green limestone. *Vascoceras cauvini*	0·8
F (10)	Rubbly limestone with interbedded harder limestones. *Burroceras*? sp., *Vascoceras cauvini*	0·7
E (10)	Rubbly, grey-green to dark grey limestone with clay and gypsum stringers. *Vascoceras cauvini* in upper part	1·2
D	Massive, grey-green, glauconitic, quartzose limestone. *Exogyra*-rich. *Nigericeras gadeni* (Chudeau)	0·9
C	Brown-yellow, calcareous sandstone	0·2
B	Ferruginous sandstone	0·0
A	Grey-green, fine-grained, poorly consolidated sandstone becoming calcareous in its upper part	2·0

The Pindiga section, or more precisely that part of it which has been seen, is as follows, from top to bottom, see Fig. 1 (numbers in parentheses are the equivalent horizons in Popoff *et al.* (1986)):

Bed		Metres
	Blue-grey shales with gypsum (base of Pindiga Formation shale member)	
V (22)	Earthy, yellow-brown, glauconitic, calcareous clay, with gypsum and white calcareous nodules. *Pseudotissotia nigeriensis, Eotissotia simplex*	0·15
	Blue-grey shales with gypsum	1·00
U (21)	Pale grey-green, poorly bedded, impure limestone. *Pseudotissotia nigeriensis, Eotissotia simplex*	0·70
T (21)	Brown-grey, poorly bedded, calcareous shale, with gypsum and shale laminae. *Pseudotissotia nigeriensis, Eotissotia simplex*	0·27
	Blue-grey shales with gypsum	0·15
S (21)	Cream-grey, irregularly bedded marl. *Pseudotissotia nigeriensis, Eotissotia simplex*	0·38
R (17)	Light grey, poorly bedded limestone with shale partings. *Pseudotissotia nigeriensis.* 7 cm hard, pale grey, nodular limestone capping	0·40
Q	Pale yellow, nodular limestone	0·06
	Blue-grey shales	0·04
	Hard, fine-grained grey limestone	0·08
P	Porous grey limestone. *Thomasites gongilensis, Pseudotissotia nigeriensis*	0·61
	Limestone, rubbly	0·12
	Hard, fine-grained grey limestone	0·08
	Blue-grey shales	2·10
O	Intensely hard, grey, orange-weathering, shelly limestone. ?*Pseudaspidoceras paganum, Vascoceras proprium globosum, Thomasites gongilensis, Pseudotissotia nigeriensis*	0·22
N (7)	Hard, grey, laminated limestone with *Thalassinoides* burrows on upper surface. *Pseudaspidoceras pseudonodosoides, Vascoceras* sp. nov. aff. *gamai, V. cauvini*	0·18
	Gypsum band	0·02
	Blue-grey shales with gypsum	0·10
M (7)	Decalcified white limestone with *Pseudaspidoceras pseudonodosoides, Vascoceras* sp. nov. aff. *gamai* and ammonite gen. et sp. nov. preserved in a white clay matrix up to	0·05
	Blue-grey shales with gypsum	0·35
	Gypsum band	0·02
(7)	Marly limestone. *Vascoceras* sp. nov. aff. *gamai*	0·08
	Gypsum band	0·02
	Blue-grey shales	0·90
(5,6)	Hard, grey, nodular limestone	0·15
	Blue-grey shales	0·10
(5,6)	Hard, grey, shelly limestone. Reworked *Vascoceras cauvini* on upper surface	0·26
I (4)	Roughly bedded, hard, grey, nodular limestone with numerous *Hemiaster*	0·45
H (4)	Intensely burrowed, pale grey marl with numerous *Hemiaster. Burroceras*? sp., *Vascoceras cauvini*	0·23
G (4)	Roughly bedded, impure limestone. *Vascoceras cauvini*	0·17
	Blue-grey shales	0·06
F (4)	Bryozoan biostrome in lower part, passing upwards into 75 cm thick *Plicatula* biostrome, with *Plicatula* becoming less common upwards	1·21
	Blue-grey shales	1·00
E	Massive, hard, pale grey limestone	0·13
	Blue-grey shales	0·50
D	Shelly, marly limestone with 1 cm shale parting in the middle	0·07
	Blue-grey shales	0·30
C	Impure limestone	0·06
	Blue-grey shales	0·20
B	Impure limestone	0·10
A (2)	Rough-bedded, grey limestone with phosphatic particles at the base. Numerous *Exogyra*; *Metengonoceras dumbli* (Cragin), *Placenticeras (Karamaites) cumminsi* (Cragin), *Nigericeras gadeni*	0·42

Unit A at Pindiga is the '*Exogyra* Limestone' of Barber (1957). Units F–I are his 'Echinoid Limestone' while units O and P are his '*Gombeoceras* Limestones 1 and 2'.

SYSTEMATIC DESCRIPTIONS

Repositories. Unless otherwise stated all the material referred to herein is in the Department of Palaeontology, The Natural History Museum, London. Only these specimens are individually identified though many additional examples of *Pseudaspidoceras pseudonodosoides* and *P. flexuosum* from Ashaka have also been studied.

Superfamily **ACANTHOCERATACEAE** Grossouvre, 1894
Family **ACANTHOCERATIDAE** Grossouvre, 1894
Subfamily **EUOMPHALOCERATINAE** Cooper, 1978
Genus ***PSEUDASPIDOCERAS*** Hyatt, 1903
(=*Ampakabites* Collignon, 1965*a*)

TYPE SPECIES. *Ammonites footeanus* Stoliczka, 1864; by original designation.

REMARKS. Proposed by Hyatt (1903: 106), the genus *Pseudaspidoceras* has subsequently been discussed by Pervinquière (1907), Freund & Raab (1969), Matsumoto (*in* Matsumoto, Kawashita, Fujishima & Miyauchi 1978), Wright & Kennedy (1981), Kennedy *et al.* (1987) and Cobban *et al.* (1989). It includes evolute ammonites with square to rectangular whorl sections. There are distant to rather dense, rounded to sharp, and rectiradiate to curved ribs in the middle whorls. Umbilical, inner and outer ventrolateral tubercles are present. Intercalated ribs frequently occur. Freund & Raab (1969: 13) considered a wide lateral lobe to be characteristic of the suture in *Pseudaspidoceras*. Matsumoto (1978) pointed out that *Mammites wingi* Morrow, 1935

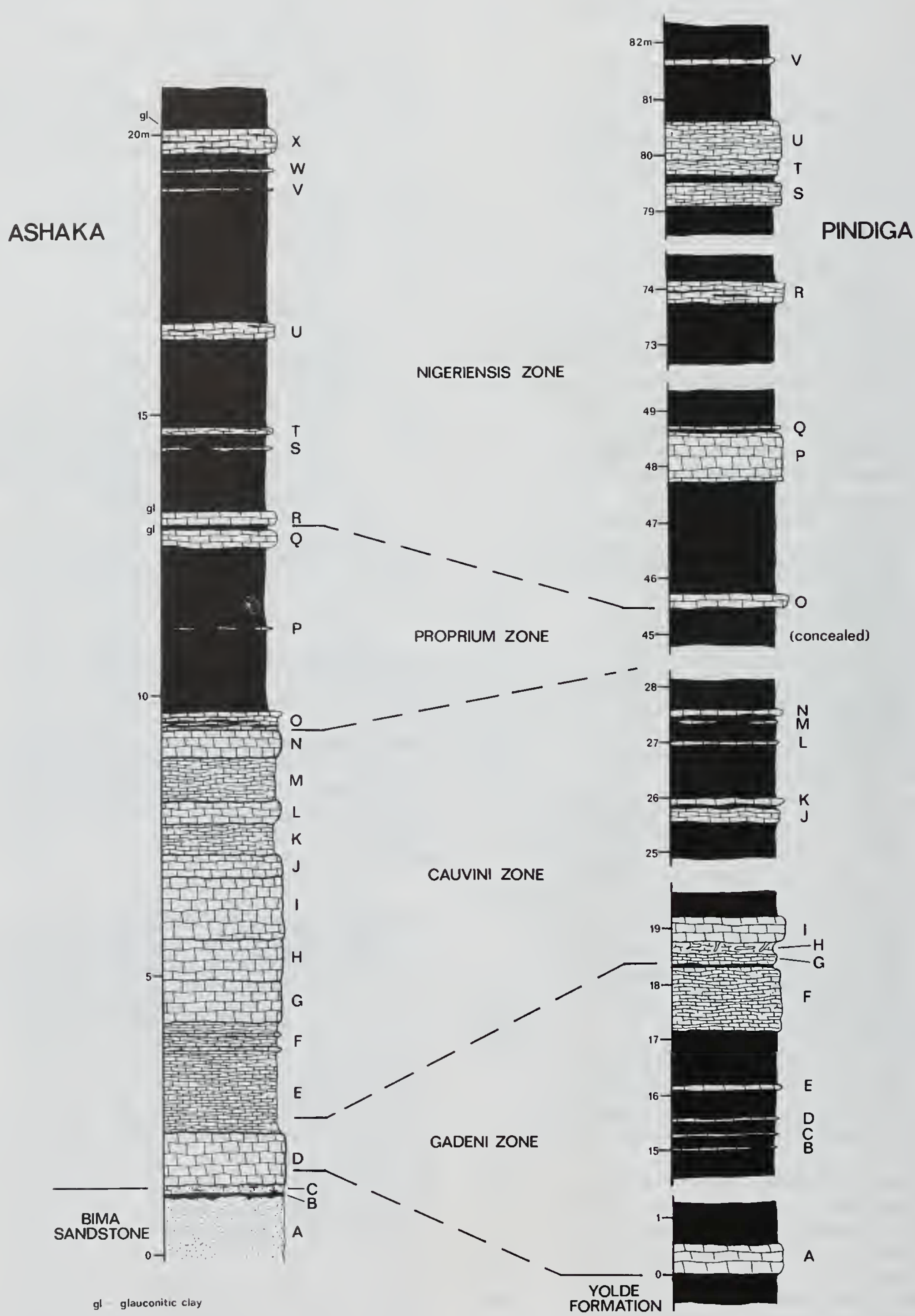


Fig. 1 Stratigraphical sections in the Pindiga Formation exposed at Ashaka Quarry and in the Pindiga stream.

and *M. dixeyi* Reyment, 1955 share this feature but these relatively involute and stout forms have since been included by Cobban & Hook (1983*a*) in their new genus *Morrowites*.

Hyatt (1903) assigned *Pseudaspidoceras* to the subfamily Mantelliceratinae. Most subsequent workers have included the genus in the Mammitinae (see, for example, Pervinquière 1907, Reyment 1955, Wright 1957, Barber 1957, Matsumoto 1978, Wright & Kennedy 1981). Descriptions of the inner whorls of *P. flexuosum* by Kennedy *et al.* (1987) and of *P. pseudonodosoides* by Cobban *et al.* (1989), however, revealed multiplication of the outer ventrolateral tubercles and the presence of constrictions, demonstrating a close relationship with *Euomphaloceras* Spath, 1923. *Pseudaspidoceras* is therefore best referred to the Euomphaloceratinae Cooper. The type species of *Ampakabites* Collignon, *Kamerunoceras (Ampakabites) auriculatum* Collignon (1965*a*: 29, pl. 388, fig. 1662; pl. 389, fig. 1664), was regarded as a synonym of *P. flexuosum* by Kennedy *et al.* (1987). Collignon (*in* Cobban & Scott 1972: 81) had, himself, earlier indicated that *Ampakabites* was better treated as a subgenus of *Pseudaspidoceras* rather than *Kamerunoceras*.

Pseudaspidoceras has a stratigraphical range from Upper Cenomanian to Lower Turonian. It occurs in Texas, New Mexico, Arizona, Colorado, Mexico, Brazil, Germany, southern England, Portugal, Tunisia, Egypt and the Middle East, Algeria, Angola, Niger, Nigeria, Madagascar, southern India and (?)Japan.

Pseudaspidoceras pseudonodosoides (Choffat, 1898)

Figs 2–5, 8, 14

1898 *Acanthoceras*(?) *pseudonodosoides* Choffat: 65, pl. 16, figs 5–8; pl. 22, figs 32, 33.
1925 *Mammites pseudonodosoides* (Choffat) Diener: 175.
1957 *Pseudaspidoceras* sp. Barber: 11, pl. 25, fig. 8.
1969 *Pseudaspidoceras cf. P. pseudonodosoides* (Choffat); Freund & Raab: 14, pl. 1, figs 10, 11; text-figs 4j–k.
1989 *Pseudaspidoceras pseudonodosoides* (Choffat); Meister: 6, pl. 2, fig. 1; text-fig. 2.
?1989 *Pseudaspidoceras* sp. Luger & Gröschke: 372, text-fig. 6I.
1989 *Pseudaspidoceras pseudonodosoides* (Choffat); Cobban, Hook & Kennedy: 40, figs 41, 81–83 (with synonymy).
1990 *Pseudaspidoceras* cf. *pseudonodosoides* (Choffat); Zaborski: figs 22a, b.

Material and occurrence. Twelve specimens, C.93333, C.93335, C.93353–4, C.93573–5, C.93982 from the Pindiga Formation, unit M, Ashaka; C.91232 from the lower part of the Dukul Formation at Dukul (see Zaborski 1990: fig. 28); C.93594 from the Pindiga Formation, unit M, Pindiga; C.93756–7, from the Pindiga Formation, Deba Habe. In addition a single specimen from the Pindiga Formation, Bularaba (C.47620, see Barber 1957: 11) has been studied. The species is very abundant in unit M at Ashaka and also occurs in some numbers in unit K there. It occurs as a rarity in units M and N at Pindiga. The Deba Habe specimens come from a 10 cm limestone occurring less than 1 m below the level at which *Vascoceras proprium costatum* and *V. nigeriense* appear. No precise stratigraphical data are available for the Bularaba specimen.

Table 1 Morphometric data for *Pseudaspidoceras pseudonodosoides* (Choffat, 1898).

	D	Wb	Wh	U
C.47620	92	36 (39)	34 (27)	36 (39)
C.91232	91	40 (44)	36 (39.6)	29 (32)
C.93574	87	–	31 (35.6)	35 (40)
C.93335	65	34 (52)	25 (38.5)	–
C.93757	58	31 (53.5)	22 (38)	20 (34.5)

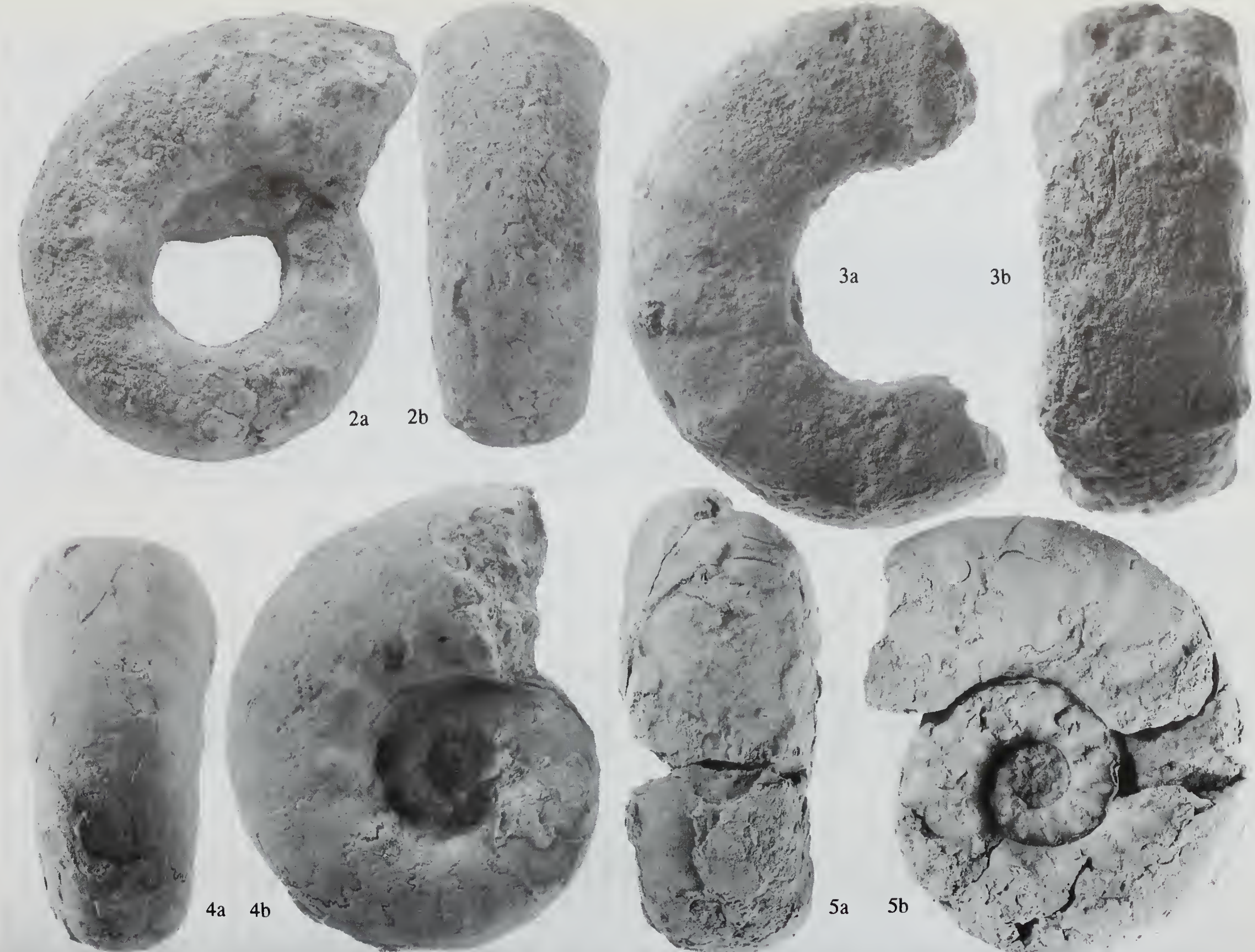
Dimensions (in mm). D, diameter; Wb, whorl breadth; Wh, whorl height; U, umbilical diameter. Figures in parentheses are dimensions as a percentage of the total diameter.

Description. Most individuals have a maximum adult diameter of 90–100 mm though some reach 120 mm. Whorl breadth is slightly to distinctly greater than whorl height.

Only in C.47620 and C.93757 (Figs 5, 8) is the ornament of the septate whorls well displayed. At a diameter of 6 mm in C.93757 there are six prominent lateral bullae in the last half whorl. They pass over the ventrolateral shoulders and merge with bullate outer ventrolateral tubercles. Isolated outer ventrolateral tubercles may be intercalated. In the last preserved whorl, up to a diameter of 58 mm, there are 9 umbilical tubercles. At first they are rounded and give rise to robust, rounded, rectiradiate ribs on the low flanks. The ribs bear a rounded inner ventrolateral tubercle but weaken as they pass over the venter where they may branch or be slightly convex. There are weak outer ventrolateral tubercles but they disappear at a diameter of 35 mm. Intercalated ventral ribs also occur; they may be as pronounced as the main ribs or take the form of fine, convex riblets. The latter type are more persistent, being present up to diameters of at least 50 mm. At diameters in excess of 45 mm the inner ventrolateral tubercles weaken, then disappear. The umbilical tubercles persist but become highly bullate and give rise to broad, rounded ribs on the inner flank region.

In C.47620 (Fig. 5) there are 13 broad, rounded, rectiradiate ribs in the whorl up to a diameter of 40 mm. Nearly all arise at prominent umbilical bullae. They weaken in the mid-flank region before bearing prominent, rounded inner ventrolateral tubercles. The latter structures have disappeared by a diameter of 45 mm. There are no outer ventrolateral tubercles at this stage. Though the earlier part of the venter in this restored specimen is concealed, Barber (1957: 11) mentioned the presence of such tubercles on the early whorls. Umbilical bullae persist onto the adult body chamber where they become weaker, elongate structures giving rise to irregularly developed, usually weak, concave ribs on the flanks. The body chamber has a rounded outline in contrast to the more rectangular, depressed section of the septate whorls.

Umbilical bullae also persist onto the body chamber in C.91232 from Dukul (Fig. 4) but here there are no flank ribs. The material from Ashaka consists almost entirely of poorly preserved body chambers which are generally smooth and with a rounded whorl section. C.93335 (Fig. 3) and C.93982 are unusual in retaining a rather rectangular whorl section and ribbing on the body chamber. In C.93982 the ribs extend from umbilical bullae across the flanks and ventrolateral shoulders where they terminate. In C.93335, however, umbilical bullae are weakly developed but ventrolateral swellings which give rise to rib-like structures on the inner part of the flank are present. C.93574 (Fig. 2) shows broad,



Figs 2–5 *Pseudaspidoceras pseudonodosoides* (Choffat). Figs 2, 3, Pindiga Formation, unit M, Ashaka. Fig. 2a, b, C.93574, x1. Fig. 3a, b, C.93335, x1. Fig. 4a, b, Dukul Formation, Dukul.

rectiradiate ribbing on the adoral part of the phragmocone but the body chamber is smooth. Certain specimens, for example that figured by Meister (1989: pl. 2, fig. 1) and C.93573, retain rather spinose ventrolateral tubercles on the body chamber.

Specimens seen in units M and N at Pindiga are all portions of the early whorls. One pathological specimen (C.93594, Fig. 14) has a diameter of some 50 mm and an ornament of umbilical bullae and abnormally developed inner ventrolateral tubercles, only one of the pair being present and displaced towards the siphonal line.

Sutures in the Nigerian material described above are relatively simple with rather short, uncomplicated elements. The lateral lobe is often unusually narrow for the genus. When it is broader it is subdivided by a short median element.

REMARKS. The lectotype of *P. pseudonodosoides* (selected by Cobban *et al.* 1989: 40) is the specimen figured by Choffat (1898: pl. 16, fig. 5). It is fully septate, has a diameter of about 90 mm, and is ornamented with strong umbilical tubercles, broad, rectiradiate ribs weakening in the mid-flank region, strong inner ventrolateral tubercles and, up to a diameter of about 60 mm, weaker outer ventrolateral tubercles. The whorls are distinctly broader than high and the venter is flattened to slightly concave. Choffat had only a few specimens at his disposal but recently Cobban *et al.* (1989) described a large collection from New Mexico which provides a wealth of information, especially regarding intraspecific variation. These forms have whorls slightly to distinctly broader than high, the flanks being flat and the venters flattened to broadly rounded. Ribs are generally rounded but may be sharp and narrow. There are 3–7 umbilical tubercles, 4–12 inner ventrolateral tubercles and 7–12 outer ventrolateral tubercles in each half whorl. Ribbing is generally best developed on the inner septate whorls while the outer ventrolateral tubercles weaken and disappear at diameters of 60–70 mm. Where they persist they may be expanded into oblique, rib-like structures. There is a great range of adult sizes but no evidence of size dimorphism; the diameter at the base of the body chamber varies from 61–182 mm, while overall maximum sizes are up to 300 mm.

The Nigerian collection conforms well with the lectotype, and, in ornament and general shell proportions, with the more coarsely decorated material from New Mexico. Although some of the latter specimens may have a comparable adult diameter, the material from north-eastern Nigeria, without regard to its exact locality, has a consistently smaller adult size of 90–120 mm. Material from Israel, referred to *P.* cf. *P. pseudonodosoides* by Freund & Raab (1969: 14–15), also includes forms reaching a diameter of over 300 mm, though some show whorls higher than broad and persistent outer ventrolateral tubercles and may be better included elsewhere. Meister (1989: 9) suggested that *P. paganum* (see below), a stratigraphically higher species, was hypermorphic in comparison to *P. pseudonodosoides*. More precisely, however, the north-eastern Nigerian poulations of the latter species are probably paedomorphic. There is no evidence of size dimorphism in this material, a similar adult size is found in all the individuals from Ashaka, Dukul and Bularaba. In this regard it is of interest to note the association of *P. pseudonodosoides* with large numbers of *Vascoceras* sp. nov. aff. *gamai* (=*Vascoceras* sp. juv. of Barber 1957: 27, pl. 5, figs 2, 4, 7; pl. 27, figs 10–15; *Plesiovascoceras* aff. gr. *thomi* (Reeside) of Meister 1989: 11, pl. 4, figs 2, 3, 5; *Paravascoceras* gr. *evolutum* (Schneegans) of Meister 1989: 14, pl. 5, fig. 4; text-fig. 10) at Ashaka, Pindiga and Deba Habe. This *Vascoceras* has an adult body chamber homeomorphic with and of comparable size (about 100 mm) to that in most of the co-occurring *P. pseudonodosoides*. The flank ribbing in the early whorls of the former may also resemble that in *P. pseudonodosoides*. The two are difficult to distinguish on the basis of poorly preserved material. The simplified suture in these *P. pseudonodosoides* even sometimes approaches that in *Vascoceras*. Size and form of *P. pseudonodosoides* in north-eastern Nigeria may have been under strong environmental control.

Pseudaspidoceras tassaraense Meister *et al.* (1992: 67, pl. 9, figs 2, 4, 7; pl. 10, figs 1, 2; text-fig. 12) from Niger is also adult at a diameter of only some 100 mm and loses its ornamentation early to develop a rounded whorl section. Meister *et al.* (1992) included the *Pseudaspidoceras* sp. of Barber (1957: 11, pl. 25, fig. 8), here considered as *P. pseudonodosoides*, in synonymy. *P. tassaraense* is closely similar to the present material and is probably conspecific.

P. tassaraense is known only from the Monts Iguellala region. Its precise stratigraphical level is difficult to determine in respect of other faunas in Niger. It occurs above *Nigericeras gadeni* and *Cibolaites*? *africaensis* Meister *et al.* (1992), the latter being unknown in Nigeria. Meister *et al.* (1992) inferred a position equivalent to a level between units R and T at Ashaka for *P. tassaraense*, that is, well above the horizons with *P. pseudonodosoides* there (units K and M). Occurring alongside *P. tassaraense* in Niger are *Nigericeras jacqueti involutum* Meister *et al.* (1992: 68, pl. 4, figs 3–5; text-fig. 14) and *Vascoceras* aff. gr. *silvanense* Choffat (Meister *et al.* 1992: 78, pl. 8, fig. 6; text-fig. 18). The *V. cauvini* which accompany *P. pseudonodosoides* in Nigeria may resemble *N. jacqueti involutum* in degree of compression and lack of juvenile ornament but are consistently more evolute. The inner whorls of certain *Vascoceras* occurring at the same levels, however, are similar to the *V.* aff. gr. *silvanense* of Meister *et al.* (1992) (see Zaborski 1991; fig. 18).

If *P. tassaraense* is conspecific with the present material then its stratigraphical level is almost certainly lower than that suggested by Meister *et al.* (1992). It would occur between their Gadeni and Cauvini zones, that is equivalent to their Pseudonodosoides to Evolutum zones in north-eastern Nigeria (Meister *et al.* 1992: figs 22–26).

Pseudaspidoceras footeanum (Stoliczka, 1864)

Figs 6, 7, 9, 10

1864 *Ammonites footeanus* Stoliczka: 101, pl. 52, figs 1, 2.
1887 *Ammonites pedroanus* White: 217, pl. 22, figs 1, 2.
1915 *Mammites (Pseudaspidoceras) footeanus*(?) (Stoliczka); Greco: 208, pl. 17, fig. 5.
1936 *Pseudaspidoceras pedroanum* (White); Maury: 231, pl. 21, figs 1, 2.
1972 *Pseudaspidoceras pedroanum* (White); Reyment & Tait: pl. 3, fig. 12.
1978 *Pseudaspidoceras* aff. *pedroanum* (White); Chancellor, Reyment & Tait: 91, figs 8–10.
1982 *Pseudaspidoceras footeanum* (Stoliczka); Chancellor: 92, figs 2A, 24, 25.
1985 *Pseudaspidoceras footeanum* (Stoliczka); Howarth: 98, figs 30–33.
1987 *Pseudaspidoceras footeanum* (Stoliczka); Kennedy, Wright & Hancock: 38, text-fig. 4.

Figs 6, 7 *Pseudaspidoceras footeanum* (Stoliczka). Pindiga Formation, unit O, Ashaka. Fig. 6a, b, C.93577, x0.67. Fig. 7a, b, C.93576, x0.75. **Fig. 8a, b** *Pseudaspidoceras pseudonodosoides* (Choffat). Pindiga Formation, Deba Habe. C.93757, x1.

igs 9, 10 *Pseudaspidoceras footeanum* (Stoliczka). Fig. 9, Pindiga Formation, unit O, Ashaka. C.93578, x0.67. Fig. 10a, b, Pindiga Formation, collected loose from the top of unit O, Ashaka. C.93362, x1. **Figs 11, 12** *Pseudaspidoceras flexuosum* Powell. Pindiga Formation, unit T2, Ashaka. Fig. 11a, b, C.93560, x1. Fig. 12a–c, C.93567, x1.

1992 *Pseudaspidoceras* gr. *pseudonodosoides* (Choffat); Courville: pl. 1, fig. 2; pl. 2, fig. 1; pl. 3, figs 1,2

MATERIAL AND OCCURRENCE. Seven specimens, C.93309, C.93362, C.93576-8, C.93764, C.93927, all from the Pindiga Formation, unit O, Ashaka, except C.93362 which was collected loose from the top of this unit. The species occurs throughout unit O both in the rubbly limestone below and the hard, nodular capping horizon.

Table 2 Morphometric data for *Pseudaspidoceras footeanum* (Stoliczka, 1864).

	D	Wb	Wh	U
C.93577	210	70 (33)	67 (32)	–
C.93309	170	65 (38)	56 (33)	–
C.93576	135	58 (43)	55 (41)	–
C.93362	65	30 (46)	27·5 (42)	22 (34)

Dimensions (in mm). D, diameter; Wb, whorl breadth; Wh, whorl height; U, umbilical diameter. Figures in parentheses are dimensions as a percentage of the total diameter.

DESCRIPTION. An evolute form with whorls a little broader than high. The flanks are flattened and the venter flattened to broadly rounded on the phragmocone, but the adult body chamber may assume an evenly rounded outline. The maximum diameter attained is about 250 mm.

The earliest growth stages have not been seen. The smallest specimen available (C.93362, Fig. 10) has a diameter of 65 mm and consists of half of one of the middle septate whorls. The flanks are flattened, the ventrolateral shoulders sloping and the venter broadly rounded. There are three prominent and four feeble umbilical bullae giving off wide to narrow ribs which weaken in the mid-flank region before passing into prominent, rounded inner ventrolateral tubercles which are also of irregular strength. The ribs curve forwards and bifurcate over the ventrolateral shoulders before terminating in well developed conical to bullate outer ventrolateral tubercles which are often obliquely directed forwards. There may be one or two pairs of outer ventrolateral tubercles intercalated with those of the main ribs.

C.93576 (Fig. 7) has a diameter of 140 mm and consists of about half of one of the later septate whorls. There are eight umbilical bullae which give rise to low, broad, rounded, mostly radial ribs which so weaken as to virtually disappear in the mid-flank region. One of the ribs bifurcates with the adoral branch curved distinctly forwards. Most of the ribs bear prominent, rounded inner ventrolateral tubercles. Occasional intercalated inner ventrolateral tubercles are present. The ribs cross the ventrolateral shoulders and terminate at weaker outer ventrolateral tubercles situated close to the siphonal line. The latter tubercles vary from spinose to rounded to bullate in shape and are situated opposite to or slightly adoral of the inner ventrolateral tubercles. They become less spinose during growth.

C.93309 has a diameter of about 170 mm and consists of the adoral part of the near-adult phragmocone and the base of the body chamber. The whorl section is subrectangular, the flanks and the venter being flattened. Umbilical bullae give rise to broad, low, unevenly developed ribs, effaced in the mid-flank region and strengthening again as they cross the ventrolateral shoulders where they pass into massive, rounded inner ventrolateral tubercles, again of uneven strength. The ribs terminate at very broad, low, rounded to bullate outer ventrolateral tubercles.

Two adult body chambers are available. C.93577 (Fig. 6) has a diameter of some 210 mm. Ornament declines markedly and the whorl section becomes broadly and evenly rounded in this individual. Towards the aperture there are narrow, sharp ventrolateral ribs of uneven strength and spacing which are asymmetrically developed on opposite sides of the specimen. There are also weak, rounded, fold-like ribs crossing the venter and extending onto the outer flanks. C.93578 (Fig. 9) has a similar diameter. The style of ribbing typical of the septate whorls extends onto the adapical part of the body chamber. The inner ventrolateral tubercles are highly spinose here. On the adoral part of the body chamber the ribs become weaker and very widely spaced while the umbilical tubercles become weak, bullate, unevenly developed structures which may be twisted backwards. Flank ribbing is virtually absent here though prominent, bullate inner ventrolateral tubercles persist and pass over the ventrolateral shoulders as narrow, rib-like structures. The sutures in this material are rather florid. The lateral lobe is very wide and subdivided by a broad but fairly low median element.

REMARKS. The lectotype of *P. footeanum* (selected by Wright & Kennedy 1981: 82) is the specimen figured by Stoliczka (1864: pl. 52, figs 1a–c) (see also Kennedy *et al.* 1987: text-fig. 4). It has a diameter of over 250 mm. The whorl section is quadrate. The ribs are generally radial and of uneven development on the later whorls. They arise from umbilical bullae but some fade before reaching the prominent inner ventrolateral tubercles. Outer ventrolateral tubercles are persistent but adorally tend to merge with the bullate inner ventrolateral tubercles to form a ventrolateral rib-like structure. A similar ornament is seen on a number of fragmentary body chambers from Angola described by Howarth (1985: 98, figs 31–33). The ornament of the lectotype and the Angolan specimens agrees well with that in the later whorls of the Nigerian material. The collection from Angola also includes one specimen showing the ornament of the middle whorls (C.81073, Howarth 1985, fig. 30). This individual closely resembles C.93362 from Nigeria though the latter has outer ventrolateral tubercles located a little further from the siphonal line and often elongated obliquely forwards.

Ammonites pedroanus White (1887: 212, pl. 22, figs 1, 2) is a synonym of *P. footeanum* (see also Chancellor 1982: 94; Bengtson 1983: 16; Howarth 1985: 98). Chancellor (1982: 95) suggested that *P. paganum* Reyment was also conspecific, along with the Nigerian specimen figured by Woods (1911: 283, pl. 23, figs 1, 2). *P. paganum* is here considered to be a distinct species while Woods' material belongs in *P. flexuosum* (see below).

The *Pseudaspidoceras* cf. *footeanum* of Wright & Kennedy (1981: 82, pl. 21, fig. 3) has whorls distinctly higher than broad. Its umbilical and inner ventrolateral tubercles are larger than those of the lectotype and the outer ventrolateral tubercles are closer to the siphonal line. In its smooth venter and prominent inner ventrolateral tubercles it is like *P. flexuosum*. The specimen is reported as coming from a stratigraphical level relatively high in the Lower Turonian (*Mammites nodosoides* Zone at Dover) whereas the Nigerian material is from the Upper Cenomanian. The *Pseudaspidoceras* sp. aff. *footeanum* of Matsumoto (*in* Matsumoto *et al.* 1978: 17, pl. 5, fig. 1) from Japan is a fragment only doubtfully referrable even to the genus.

Pseudaspidoceras footei var. *grecoi* Collignon (1965*b*: 176, pl. E, figs 1a, b; Collignon & Roman *in* Amard *et al.* 1981: pl. 5, figs 1a, b) is a highly evolute form with a subquadrate whorl section a little higher than broad. Narrow, radial ribs, effaced in the mid-flank, arise from umbilical bullae and bear prominent inner ventrolateral tubercles. Intercalated ribs arise upon the outer flanks. All the ribs cross the ventrolateral shoulders but do not reach the siphonal line. In its whorl section and ornament this form is rather closer to *P. paganum* (see below) than to *P. footeanum*.

Pseudaspidoceras reesidei Benavides-Cáceres (1956: 468, pl. 54, figs 1–4; text-fig. 51) is a moderately depressed species with an ornament similar to that in *P. footeanum*. The former is, however, less evolute and its lateral lobe is subdivided by a very low median element; in these respects it more resembles *Morrowites*.

The *Acanthoceras*(?) cf. *footeanus* of Choffat (1898: 66, pl. 6, fig. 5) seems to be adult at a diameter of less than 90 mm. There are strong, rectiradiate ribs on the phragmocone while the mainly smooth body chamber has weak, irregularly developed, closely spaced ribs. The suture is unknown. This form resembles the adults of *P. pseudonodosoides* from Nigeria described above.

Pseudaspidoceras paganum Reyment, 1954*a*

Figs 15, 16, 22, 23

1954*a* *Pseudaspidoceras paganum* Reyment: 253, pl. 4, fig. 1; text-figs 3h, 4.
1955 *Pseudaspidoceras curvicostatum* Reyment: 55, pl. 11, fig. 1; pl. 12; text-fig. 24.
1989 *Pseudaspidoceras paganum* Reyment; Meister: 6 (*pars*), pl. 1, fig. 1; text-fig. 3.
1990 *Pseudaspidoceras* cf. *flexuosum* Powell; Zaborski: fig. 23 (only).
1991 *Pseudaspidoceras flexuosum* Powell; Courville *et al.*: 1041.

MATERIAL AND OCCURRENCE. Ten specimens, C.91275, C.93331, C.93537, C.93918–9, C.93920, C.93924–6, from the Pindiga Formation, unit R (upper surface), Ashaka; C.93923, and the holotype (C.47422), are specimens collected loose from the Pindiga Formation, Pindiga but their matrix strongly suggests derivation from unit O there.

Table 3 Morphometric data for *Pseudaspidoceras paganum* Reyment, 1954a.

	D	Wb	Wh	U
C.93331	146	55 (38)	58 (40)	45 (31)
C.93924	143	48 (33.5)	50 (35)	53 (37)
C.93925	140	49 (35)	52 (37)	50 (36)
C.93537	135	46 (34)	50 (37)	52 (38·5)
C.93919	115	44 (38)	48 (39)	42 (36·5)

Dimensions (in mm). D, diameter; Wb, whorl breadth; Wh, whorl height; U, umbilical diameter. Figures in parentheses are dimensions as a percentage of the total diameter.

DESCRIPTION. The whorls are quadrate or, more usually, a little higher than broad. Maximum whorl breadth is at the level of the umbilical tubercles. The flanks converge slightly upon the flattened to broadly rounded venter. At diameters of less than 7 mm the whorls are ovoid and smooth. By diameters of 20–25 mm there are narrow, fairly sharp, radial to slightly convex ribs. They mostly arise at feeble umbilical bullae and bear weak inner ventrolateral tubercles. They curve forwards over the ventrolateral shoulders and terminate in pronounced outer ventrolateral tubercles which are elongated obliquely forwards. By diameters of 40–45 mm the outer ventrolateral tubercles are more rounded in shape, there being 2 or 3 for each inner ventrolateral tubercle. At diameters of 50–60 mm the inner and outer ventrolateral tubercles are of equal strength. At larger diameters the ribs become unevenly developed. They are radial, convex or flexuous in shape but may be effaced in the mid-flank region. Most arise at variably developed umbilical bullae and all bear bulbous to spinose inner ventrolateral tubercles which become the most pronounced ornamental feature. Other ribs arise in the mid-flank region and there may be pairs of additional intercalated inner ventrolateral tubercles. Situated adoral of the inner ventrolateral are rounded to clavate outer ventrolateral tubercles. There are usually 1–3 pairs of additional outer ventrolateral tubercles between successive pairs of inner ventrolaterals. These tubercles are of variable strength and are sometimes asymmetrically developed. The inner and outer ventrolateral tubercles persist as discrete structures to the largest diameters seen, of nearly 150 mm. In the later growth stages there may be weak, fold-like structures upon the flanks between the main ribs.

REMARKS. Chancellor (1982: 95) suggested that *P. paganum* was a synonym of *P. footeanum*. The two are similar but whorl breadth generally exceeds whorl height in the latter while the opposite condition prevails in *P. paganum*. The inner and outer ventrolateral tubercles also persist as discrete structures to larger diameters in *P. paganum*; in *P. footeanum* these tubercles take the form of bullate swellings on ventrolateral rib-like structures in the later growth stages. *P. paganum* has a more rounded venter and its sutural elements are more elongate and finely subdivided.

Pseudaspidoceras curvicostatum Reyment (1955: 55, pl. 11, fig. 1; pl. 12; text-fig. 24) is a synonym of *P. paganum* (see also Chancellor 1982: 92). The holotype (C.54801) is from the Abazi River at Ezillo in south-eastern Nigeria. The species was distinguished mainly on the basis of its strongly curved ribs. As described above, however, this condition is also found in the later growth stages in *P. paganum*.

The *Acanthoceras* cf. *footeanum* (Stoliczka) of Eck (1914: 196, pl. 17, figs 1, 2) is represented by a poorly preserved specimen with whorls higher than broad and marked inner and outer ventrolateral tubercles up to a diameter of at least 50 mm. This form may be most closely related to *P. paganum*. As mentioned above *P. footei* var. *grecoi* Collignon also shows similarities with *P. paganum*.

Specimens referred to *P. paganum* by Barber (1957: 9) are better placed in *P. flexuosum* (see below). Meister (1989: 8) reported *P. paganum* from units O and R at Ashaka. All members of the genus found in unit O during the present work, however, are best referred to *P. footeanum*. The *P. flexuosum* of Courville *et al.* (1991) are *P. paganum*.

Pseudaspidoceras flexuosum Powell, 1963

Figs 11–13, 17, 18, 20, 21

1902 *Mammites footeanus* Stol. spec. Petraschek: 144, pl. 9, fig. 1.

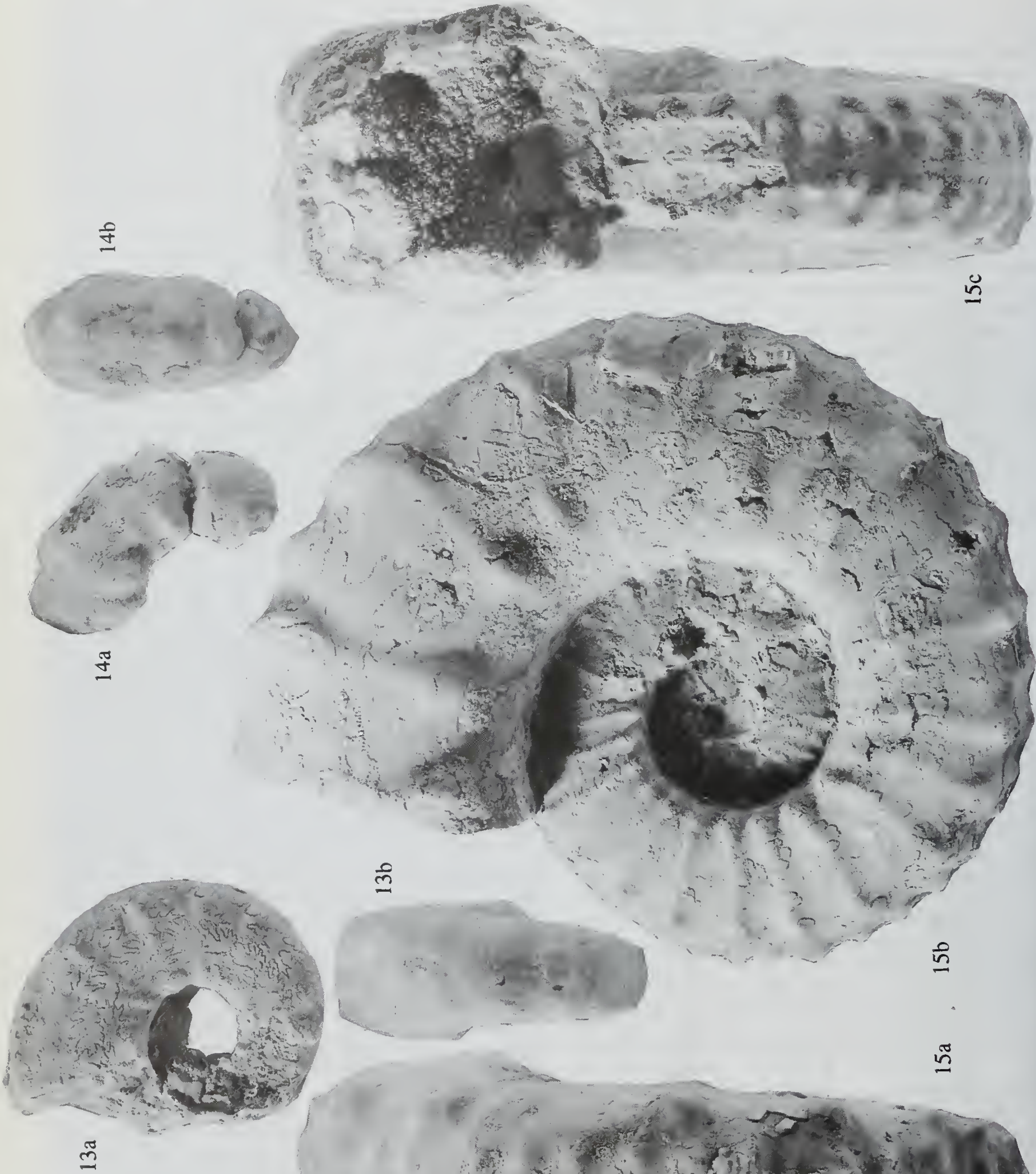
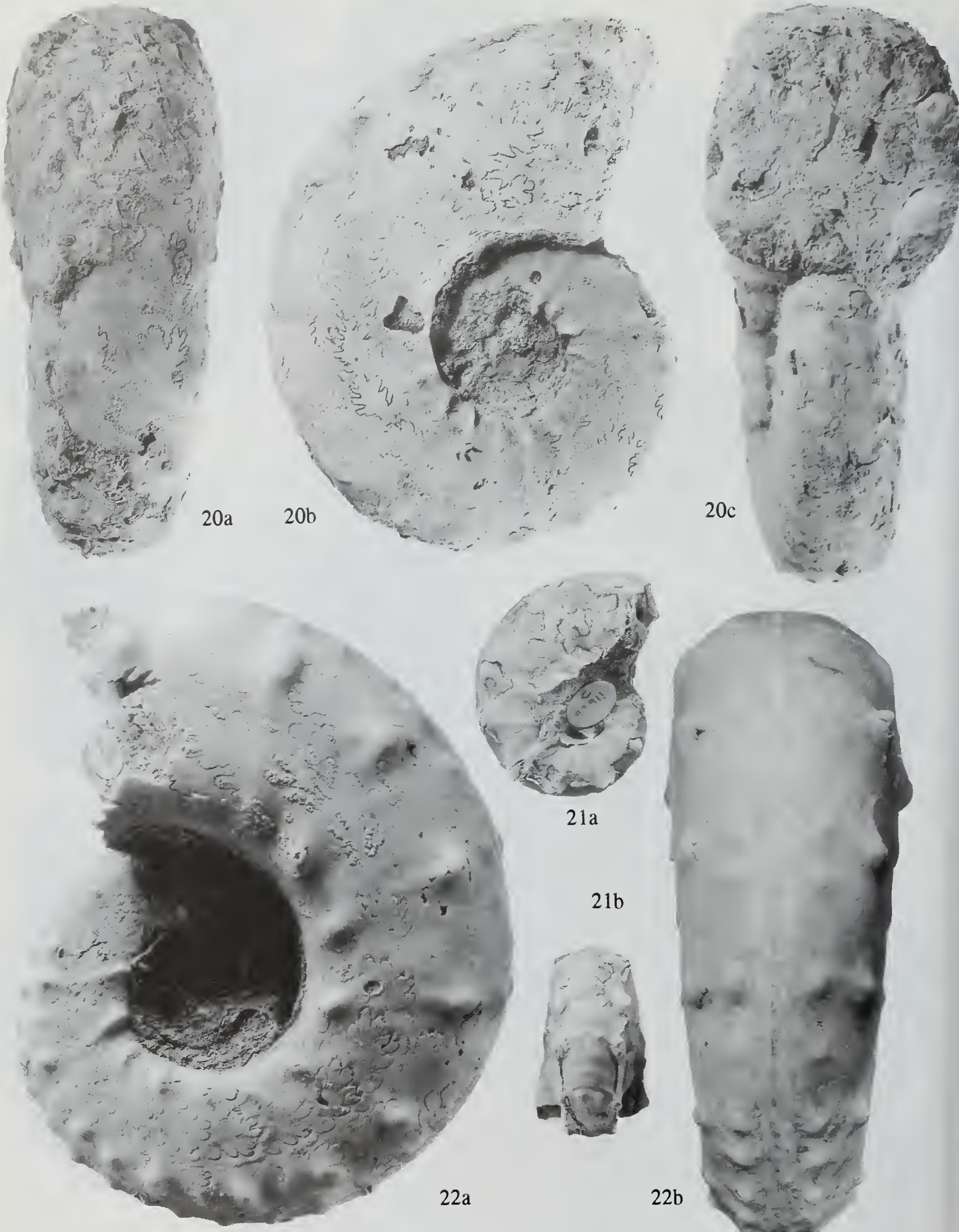


Fig. 13a, b *Pseudaspidoceras flexuosum* Powell. Pindiga Formation, unit T2, Ashaka. C.93563, x1.
Fig. 14a, b *Pseudaspidoceras pseudonodosoides* (Choffat). Pindiga Formation, unit M, Pindiga. C.93594, x1.

g. 16a, b *Pseudaspidoceras paganum* Reyment. Pindiga Formation, unit R, Ashaka. C.93331, x0.67. **Figs 17, 18** *Pseudaspidoceras flexuosum* Powell. Fig. 17, a, b, Pindiga Formation, unit T2, Ashaka. C.93366, x1. Fig. 18a, b, collected loose from the Pindiga Formation, Pindiga. C.91276, x1. **Fig. 19** *Burroceras*? sp. Pindiga Formation, unit H, Pindiga. C.93369, x1.



Figs 20, 21 *Pseudaspidoceras flexuosum* Powell. Pindiga Formation, unit T2, Ashaka. Fig. 20a–c, C.93367, x1. Fig. 21a, b, C.93911, x1.
Fig. 22a, b *Pseudaspidoceras paganum* Reyment. Pindiga Formation, unit R, Ashaka. C.93919, x1.

1911 *Mammites (Pseudaspidoceras)* sp. Woods: 283, pl. 23, figs 1, 2.
1920 *Pseudaspidoceras* aff. *pedroanum* (White); Böse: 209, pl. 13, fig. 1; pl. 15, fig. 1.
1957 *Pseudaspidoceras paganum* Reyment; Barber: 9, pl. 1, figs 1, 2; pl. 25, figs 5–7.
1963 *Pseudaspidoceras flexuosum* Powell: 318, pl. 32, figs 1, 9, 10; text-figs 2a–c, f, g.
1965*a* *Kamerunoceras (Ampakabites) auriculatum* Collignon: 29, 31, pl. 388, fig. 1662; pl. 389, fig. 1664.
1972 *Ampakabites collignoni* Cobban & Scott: 81, pl. 29, figs 1–3; text-figs 39, 40.
1987 *Pseudaspidoceras flexuosum* Powell; Kennedy, Wright & Hancock: 34, pl. 2, figs 1–4, 8–13, 16, 17; text-figs 3A–C, 5, 6C, D, 7A–C.
1989 *Pseudaspidoceras barberi* Meister: 8, pl. 1, fig. 2; pl. 2, figs 2, 5; text-fig. 4.
1989 *Pseudaspidoceras flexuosum* Powell; Cobban, Hook & Kennedy: 41, fig. 91L.
1990 *Pseudaspidoceras* cf. *flexuosum* Powell; Zaborski: fig. 24 (only).
1990 *Pseudaspidoceras flexuosum* Powell; Amêdro *in* Robaszynski *et al.*: 264, pl. 17, fig. 1; pl. 18, fig. 1.
1992 *Pseudaspidoceras barberi* Meister; Courville: pl. 2, fig. 2.

MATERIAL AND OCCURRENCE. Nineteen specimens, C.93366–8, C.93560–7, C.93911–7, from the Pindiga Formation, unit T2, Ashaka; C.91276, collected loose from the Pindiga Formation, Pindiga.

Table 4 Morphometric data for *Pseudaspidoceras flexuosum* Powell, 1963 (see also Barber 1957: 9).

	D	Wb	Wh	U
C.93367	112	42 (37·5)	46 (41)	35 (31)
C.93567	98	42 (43)	42 (43)	30 (31)
C.93368	91	38 (42)	43 (47)	26 (28·5)
C.93366	83	31 (37)	40 (48)	25 (30)
C.93566	81	28 (34·5)	38 (47)	25 (31)
C.91276	75	29 (39)	34 (45)	–
C.93565	72	32 (44)	34 (47)	–
C.93564	66	28 (42)	30 (45)	20 (30)
C.93562	50	20 (40)	22 (44)	–

Dimensions (in mm). D, diameter; Wb, whorl breadth; Wh, whorl height; U, umbilical diameter. Figures in parentheses are dimensions as a percentage of the total diameter.

DESCRIPTION. Although whorl height is generally a little to markedly greater than whorl breadth, exceptional specimens show quadrate whorls. The latter tend to have rather flattened venters but in most cases the flanks are flattened and the venters broadly rounded in this material.

C.93560 (Fig. 11) shows the ornament at a diameter of less than 30 mm. There are 10–11 ribs in the last whorl which arise at umbilical bullae. They bear prominent, bulbous to clavate inner ventrolateral tubercles at which they loop forwards over the venter and branch into pairs. The adapical rib of each pair bears weak, nodate outer ventrolateral tubercles located close to the siphonal line; the adoral rib is a simple untuberculated structure curved convexly forwards.

The ornament of the middle whorls is variable. The ribs may be fairly broad and radial in disposition, distinctly curved, or flexuous. They may be effaced in the mid-flank region and often branch. All the main ribs arise at umbilical tubercles, which are often of variable strength. They may be bullate or spinose and twisted backwards. Each rib bears a prominent, bulbous to bullate inner ventrolateral tubercle, these structures outnumbering the umbilical tubercles where the ribs branch. In other cases, ribs fade before reaching the ventrolateral shoulder and here the umbilical tubercles outnumber the inner ventrolaterals. Across the venter each rib bears a pair of weak outer ventrolateral tubercles located close to the siphonal line and a little adoral of the inner ventrolaterals. There may be additional weak intercalated ventral ribs curved convexly forwards and without tubercles, or additional pairs of isolated outer ventrolateral tubercles may occur.

The outer ventrolateral tubercles may already have disappeared at diameters of about 50 mm or they may persist until diameters in excess of 100 mm. After they have faded the venter is broadly arched and flanked by prominent inner ventrolateral tubercles. Weak, convexly curved ventral ribs may persist up to diameters as large as 120 mm. No adult body chamber is available. The sutures are complex with narrow, elongate, finely subdivided saddles. The lateral lobe is broad and divided, often asymmetrically, by a narrow, elongate median element.

REMARKS. Chancellor (1982: 95) suggested that the Nigerian ammonite described by Woods (1911: 283, pl. 23, figs 1, 2) (specimen B3240 in the Sedgwick Museum, Cambridge) was referrable to *P. paganum* and that this species was a probable synonym of *P. footeanum*. He doubted, however, that all the material referred to *P. paganum* by Barber (1957: 9) belonged in *P. footeanum*. Similarly, Kennedy *et al.* (1987: 68) thought that Barber's material was in part *P. flexuosum*. Here, all this Nigerian material is included in *P. flexuosum*, along with *P. barberi* Meister (1989: 8).

The most detailed previous description of *P. flexuosum* was based on a large collection from west Texas (Kennedy *et al.* 1987: 34). The early whorls in the Nigerian material are entirely comparable with those in the Texan specimens. The minor differences in the later growth stages of the Nigerian forms, occasional large whorl breadth and relatively coarse flank ribbing, can be ascribed to individual variation. Considerable inconsistency is displayed in these features by the Ashaka specimens though they all come from a single 5–6 cm calcareous clay horizon. The variation is sufficient to encompass Woods' and Barber's material. *P. paganum* has consistently broader whorls, more pronounced, spinose and persistent outer ventrolateral tubercles located a little further away from the siphonal line, and a less complex suture. Courville (1992: 423–424) reported *Pseudaspidoceras barberi* (= *P. flexuosum*) from unit U (his level 32) at Ashaka. The fauna described by him, however, is that of unit T2 (upper part of his level 30).

Genus *BURROCERAS* Cobban, Hook & Kennedy, 1989

TYPE SPECIES. *Burroceras clydense* Cobban, Hook & Kennedy, 1989; by original designation.

REMARKS. *Burroceras* was proposed by Cobban, Hook & Kennedy (1989: 37) for material from New Mexico transitional in form and age from *Euomphaloceras* to *Pseudaspidoceras*. It combines the shell form and suture pattern of *P.*

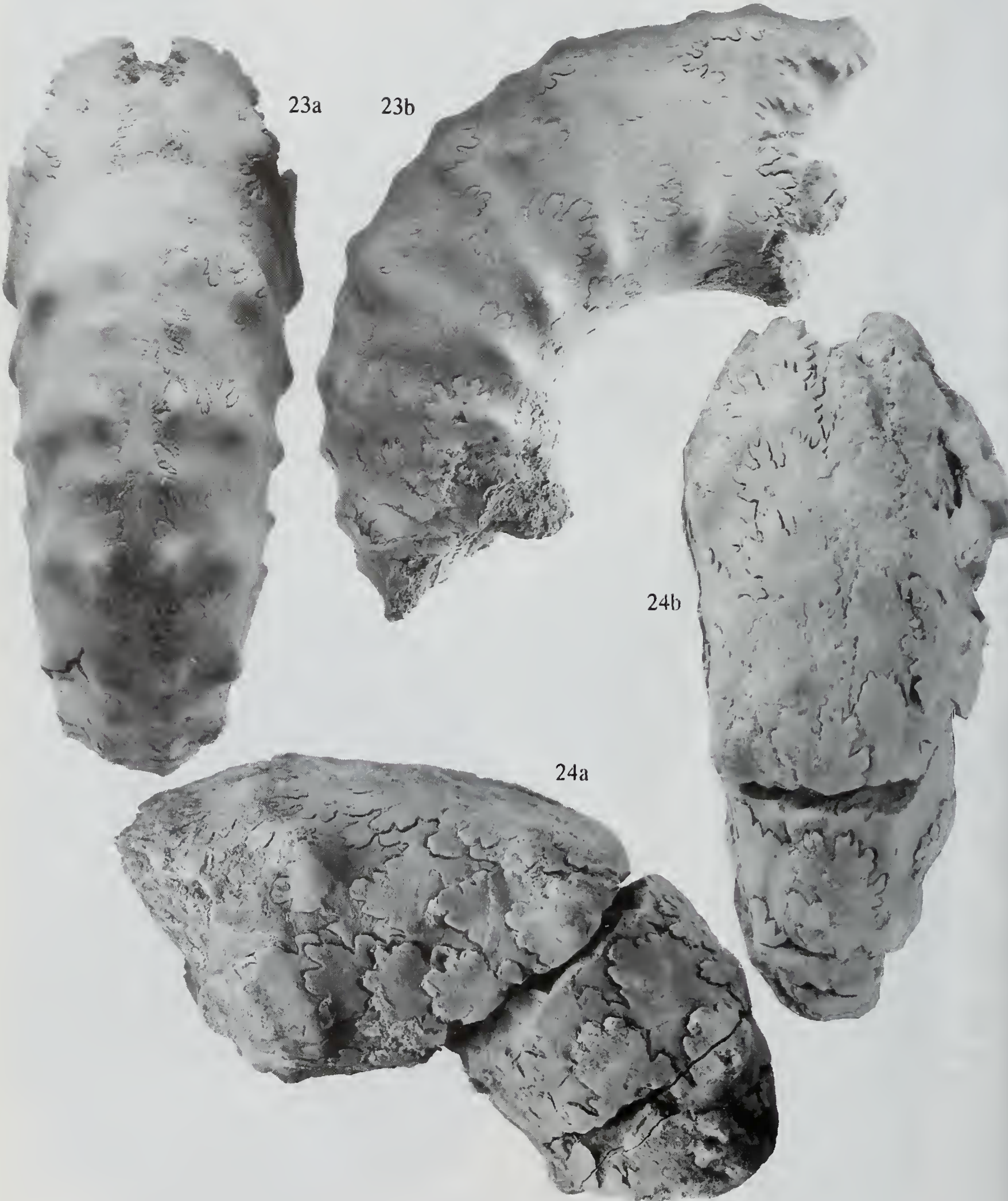


Fig. 23a, b *Pseudaspidoceras paganum* Reyment. Pindiga Formation, unit R, Ashaka. C.93918, x1.
Fig. 24a, b *Burroceras*? sp. Pindiga Formation, unit F, Ashaka. C.93572, x1.

pseudonodosoides with the tubercle distribution of *E. euomphalum* (Sharpe), siphonal tubercles being present. Three species were identified, all of Late Cenomanian age: *B. clydense* Cobban, Hook & Kennedy (1989: 38, figs 38, 79D–G, N–T) with a prominent ornament including ventrolateral horns and marked siphonal clavae; *B. irregulare* Cobban, Hook & Kennedy (1989: 38, figs 39, 80S–V) with an ornament of highly irregular strength; and *B. transitorium* Cobban, Hook & Kennedy (1989: 39, figs 40, 79A–C, 80D–R) distinguished chiefly by its weak siphonal ornament.

***Burroceras*? sp.** Figs 19, 24

MATERIAL AND OCCURRENCE. Three specimens, C.93369–70, from the Pindiga Formation, unit H, Pindiga; C.93572, from the Pindiga Formation, unit F (upper part), Ashaka.

DESCRIPTION. C.93370 is part of a body chamber with a diameter of some 120 mm. Umbilical bullae give rise to robust flank ribbing. There are strong, rather clavate inner ventrolateral tubercles but the ventral area is poorly preserved making identification of any ornament difficult. C.93369 (Fig. 19) is a more complete specimen with a diameter of 125 mm and consisting of one septate whorl and about half a whorl of body chamber. There are narrow, radial ribs of moderate strength on the septate whorl which arise from umbilical bullae and bear prominent inner ventrolateral tubercles. Again the ventral area is poorly preserved.

C.93572 (Fig. 24) is part of a septate whorl with a diameter of about 130 mm. Whorl breadth slightly exceeds whorl height. The flanks are flattened and the venter broadly rounded. There are distant umbilical bullae of moderate strength giving rise to low, rounded ribs which weaken in the mid and outer flank regions. They bear fairly strong, rounded inner ventrolateral tubercles at which they bend forwards and become weak, broad structures before terminating at smaller, rounded outer ventrolateral tubercles. There are vague traces of siphonal swellings but it is difficult to determine if they are real or preservational features. The suture shows a broad, low median element subdividing the lateral lobe.

REMARKS. This material, from horizons low in the Ashaka and Pindiga sections, differs from the earliest *Pseudaspidoceras*, *P. pseudonodosoides*, in the retention of discrete outer ventrolateral tubercles until larger diameters. Unfortunately, positive identification of siphonal ornament is not possible in these specimens and consequently they can only be tentatively referred to *Burroceras*. Of the three species proposed by Cobban *et al.* (1989) in New Mexico the present material most closely resembles *B. transitorium* in ornamental style and suture pattern. In particular the siphonal tubercles, located on a siphonal ridge which disappears on the adult body chamber, are very weak, often barely noticeable in this species.

STRATIGRAPHICAL DISCUSSION

Several biostratigraphical schemes based on ammonites have been put forward for the Cenomanian-Turonian beds in north-eastern Nigeria (see Reyment 1954*a*, 1954*b*, Barber 1957, Wozny & Kogbe 1983, Popoff *et al.* 1986, Meister 1989, Zaborski 1990, including a review, Courville *et al.* 1991). That proposed by Zaborski (1990) is maintained here. Briefly, five biozones were recognized, all defined at their bases by the appearances of the nominal species. They are, from oldest to youngest: a Zone of *Nigericeras gadeni*; a Zone of *Vascoceras cauvini*; a Zone of *Vascoceras proprium*, defined at its base by the appearance of *V. proprium costatum*, two further subspecies, *V. proprium globosum* (basal Proprium to basal Nigeriensis Zone) and *V. proprium proprium* (lower Nigeriensis Zone), being recognizable in the region; a Zone of *Pseudotissotia nigeriensis*; and a Zone of *Wrightoceras wallsi* Reyment. The stratigraphical distribution of *Burroceras*(?) and the various species of *Pseudaspidoceras* within this framework is as follows: *Burroceras*(?), lower part of the Cauvini Zone; *P. pseudonodosoides*, upper part of the Cauvini Zone; *P. footeanum*, lower part of the Proprium Zone; *P. paganum*, basal Nigeriensis Zone; and *P. flexuosum*, lower part of the Nigeriensis Zone (see Fig. 1).

The best dated occurrences of *Pseudaspidoceras* elsewhere in the world are in New Mexico and west Texas (see Hook & Cobban 1981, Cobban & Hook 1983*a*, 1983*b*, Cobban 1984, Kennedy *et al.* 1987, Cobban *et al.* 1989). In these areas only *P. pseudonodosoides* and *P. flexuosum* are known, but in south-western New Mexico *Burroceras* is also present. The following biozones have been recognized in the Upper Cenomanian and Lower Turonian there (Cobban *et al.* 1989):

Lower Turonian	Zone of *Mammites nodosoides* (Schlüter)
	Zone of *Vascoceras birchbyi* (Cobban & Scott)
	Zone of *Pseudaspidoceras flexuosum* Powell
Upper Cenomanian	Zone of *Neocardioceras juddii* (Barrois & Guerne)
	Zone of *Burroceras clydense* Cobban, Hook & Kennedy
	Zone of *Sciponoceras gracile* (Schumard)
	Zone of *Metoicoceras mosbyense* Cobban
	Zone of *Calycoceras canitaurinum* (Haas)

Burroceras clydense is the earliest known member of its genus. *B. irregulare* and *B. transitorium*, along with *Pseudaspidoceras pseudonodosoides*, are Juddii Zone forms. *P. flexuosum* characterizes the lowest Turonian zone recognizable. There is, however, an hiatus horizon at the top of the Juddii Zone in south-western New Mexico and it is at this level that *P. pseudonodosoides* occurs; latest Cenomanian beds equivalent in age to the Zone of *Nigericeras scotti* Cobban in south-east Colorado and north-east New Mexico are missing.

The Gracile Zone in New Mexico can be correlated with the Nigerian Gadeni Zone as both contain *Metoicoceras geslinianum* (d'Orbigny) (see Cobban *et al.* 1989, Zaborski 1990). The Nigerian Cauvini Zone is, at least in part, the equivalent of the Juddii Zone as developed in south-west New Mexico. The *Burroceras*(?) in unit F at Ashaka and unit H at Pindiga cannot be identified to species level but appears closest to *B. transitorium*, a Juddii Zone form. Equivalents of the Clydense Zone cannot therefore be positively identified in north-east Nigeria at present. *Burroceras*(?) in Nigeria is associated with early *Vascoceras cauvini* which may closely resemble *V. barcoicense* Choffat *exile* Cobban, Hook & Kennedy (1989: 47, figs 47, 87Q–S, 89M–GG), at least in the middle whorls, but the latter ranges from the Clydense to the Juddii Zone in New Mexico.

Units K and M at Ashaka and M and N at Pindiga, which contain the known stratigraphical range of *P. pseudonodosoides*, can be correlated with the upper part of the Juddii Zone in south-western New Mexico. Lying disconformably above in the latter region are sandy beds containing the *P. flexuosum* fauna. This species occurs in unit T2 at Ashaka. As explained below, there are no equivalents in south-western New Mexico of units N to T1 at Ashaka. At Pindiga the corresponding part of the sequence is largely unexposed, though units O and P comprise a portion of it. The missing part of the sequence in south-western New Mexico corresponds to that containing *P. footeanum* and *P. paganum* in Nigeria. In unit T2 at Ashaka *P. flexuosum* is accompanied by large numbers of *Pseudotissotia nigeriensis* and in addition *Vascoceras proprium proprium*, *V. obscurum*, *Thomasites gongilensis*, *Choffaticeras* sp., *Watinoceras* aff. *coloradoense* and *Wrightoceras munieri* (=*W. wallsi* of Meister 1989: pl. 28, fig. 2). This fauna is of closely similar age to that from west Texas described by Kennedy *et al.* (1987) and taken to characterize the basal Turonian Zone of *Pseudaspidoceras flexuosum* there. Apart from *P. flexuosum*, *Thomasites*, *V. proprium proprium* and *W. munieri* are notable common elements. The appearance of *P. flexuosum* in the west Texas-New Mexico area was suggested as a marker for the base of the Turonian stage by Kennedy (1984) (see also Cobban 1984, Birkelund *et al.* 1984: 12). Hancock (1984, 1991) further suggested that *V. proprium proprium* might perform the same stratigraphical function but at Ashaka this form occurs in unit T1, immediately below the first occurrence of *P. flexuosum*. On the basis of the appearance of *P. flexuosum*, the base of the Turonian coincides with the base of unit T2 at Ashaka. The top of unit T1 is a discontinuity surface, overlain by a thin layer of diagenetic gypsum, while unit T2 which has a high content of glauconite and phosphatic matter is condensed. Construction of a correlation line between the Ashaka and Pindiga sections indicates that the Cenomanian-Turonian boundary in the latter occurs about 56 m above the base of the lowest limestone unit (A, see Fig. 1). This portion of the section is unexposed. A single specimen of *P. flexuosum* (C.91276, Fig. 18) has been found at Pindiga but its precise horizon is unknown.

Courville *et al.* (1991), it should be noted, placed the Cenomanian-Turonian boundary within what is regarded here as the Upper Cenomanian since specimens of *P. paganum* from both northern and southern Nigeria were misidentified as *P. flexuosum*. Their *P. barberi* are synonymous with *P. flexuosum*.

The Cenomanian-Turonian boundary in north-eastern Nigeria occurs in the lower part of the Nigeriensis Zone. The earliest forms here referred to *Pseudotissotia nigeriensis* (from unit R at Ashaka and unit O at Pindiga), however, do not develop the typically tricarinate venter until relatively large diameters of 50–60 mm. These individuals are morphologically intergradational with their prolific associate *Thomasites gongilensis*. There is little doubt that *P. nigeriensis* was derived from the latter species (see also Barber 1957, Meister 1989). A clear distinction between the two cannot be made at these stratigraphical levels. Meister (1989) evidently referred the entire assemblage from unit R at Ashaka to *T. gongilensis*. Undoubted examples of *P. nigeriensis* do, nevertheless, appear before *Pseudaspidoceras flexuosum*; they are abundant in unit T1 at Ashaka. It may also be noted here that the identification of the Zone of *Wrightoceras wallsi* at Ashaka and Pindiga by Zaborski (1990) was based on previous reports of the occurrence of that species (see Barber 1957, Popoff *et al.* 1986). Its presence has not been confirmed in this work and the zone is not, therefore, indicated in Fig. 1. Identifications of *W. wallsi* from unit T at Ashaka by Meister (1989) are here regarded as dubious; the material is, at least in part, *W. munieri*.

If unit T2 at Ashaka represents the basal Turonian then *Pseudaspidoceras footeanum* and *P. paganum* are Late Cenomanian in age. *P. footeanum* was assigned to the Lower Turonian in Angola by Howarth (1985). Bengtson (1983: 44) also recorded the species from the Lower Turonian in Brazil but, in addition, listed similar forms from the high Cenomanian. Records of *P. footeanum*, however, reveal little accurate dating against other ammonites. The Nigerian examples, from unit O at Ashaka, come from a stratigraphical level higher than that of the Juddii Zone but lower than that of the Flexuosum Zone in south-western New Mexico. Unit O contains an ammonite assemblage dominated by species of *Vascoceras*. Prominent within the fauna are multituberculated forms with simplified sutures (*Nigericeras* and *Paramammites* of Barber 1957, and *Vascoceras costatum* (Reyment) and *Paramammites subconciliatus* (Choffat) of Meister 1989). This group shows a morphological gradation into smoother ammonites referrable to *Vascoceras nigeriense* Woods (1911: 281, pl. 21, fig. 6; pl. 22, figs 2, 3). The more strongly ornamented examples frequently resemble *Nigericeras scotti* Cobban (1971: 18, pl. 9, figs 1–4; pl. 18, figs 1–9; text-figs 15–19), the nominal species for the topmost Cenomanian zone recognizable in south-west Colorado and north-east New Mexico.

The *Pseudaspidoceras* cf. *footeanum* of Wright & Kennedy (1981: 82, pl. 21, fig. 3) is reported as coming from a much higher stratigraphical level (the *Mammites nodosoides* Zone of southern England) but, as mentioned above, probably does not belong in *P. footeanum*.

The exact stratigraphical level of the holotype of *P. paganum* at Pindiga is uncertain. It is preserved in a hard, orange-weathering limestone matrix closely matching unit O there. The same is true of specimen C.93923, collected loose at Pindiga. This bed is their probable source, especially as it contains an ammonite fauna otherwise identical to that of unit R at Ashaka, in which *P. paganum* is known to occur: *Thomasites gongilensis* at its acme, *Vascoceras proprium globosum* and the earliest *Pseudotissotia nigeriensis*. Units O and P are the '*Gombeoceras* Limestones 1 and 2' of Barber (1957) which make up his Zone of *Paravascoceras costatum* (Reyment). Barber (1957: table 3) listed a number of species additional to those mentioned above which were said to characterize these horizons. These forms, however, are probably derived from loose limestone blocks found scattered in gullies and fields at a stratigraphical level between units N and O at Pindiga. These blocks yield elements of the fauna characterizing the Proprium Zone elsewhere including *Vascoceras nigeriense*.

Pseudaspidoceras pseudonodosoides is well dated in Israel where it is found in the *Vascoceras cauvini* Zone (Freund & Raab 1969), a correlative of the Juddii Zone in north-west Europe, and in the New World (Lewy *et al.* 1984). This stratigraphical occurrence is in accord with that in north-eastern Nigeria. In Portugal the species occurs at the base of the equivalent of the Juddii Zone but is recorded as ranging into the Lower Turonian (Berthou 1984, Berthou *et al.* 1985). *P. footeanum* is indicated as occurring low in the Juddii Zone. Similarly, in Israel Freund & Raab (1969) indicated both *P. footeanum* and *P.* cf. *P. paganum* as coming from the Cauvini Zone alongside *P. pseudonodosoides*. These species have a clear stratigraphical separation in north-eastern Nigeria and such records require confirmation.

Amêdro (*in* Robaszynski *et al.* 1990: 264) listed the order of stratigraphical occurrence of species of *Pseudaspidoceras* as: *P. pseudonodosoides* (Juddii Zone), *P. flexuosum* (basal Turonian) and *P. footeanum* (Nodosoides Zone). This interpretation seems to have been influenced by the description of *P.* cf. *footeanum* from the Nodosoides Zone by Wright & Kennedy (1981). However, as mentioned above, this specimen is closer to *P. flexuosum* but, even so, appears to occur anomalously high.

The expanded sequences across the Cenomanian-Turonian boundary in north-eastern Nigeria provide the best documented details available to date concerning the stratigraphical distribution of *Pseudaspidoceras* as a whole. Clearly the genus has great potential value in detailed correlation at these levels. Its occurrence in north-eastern Nigeria can be summarized as follows: *P. pseudonodosoides* occurs high in the Cauvini Zone equivalent to the upper part of the Juddii Zone elsewhere in the world and is thus of Late Cenomanian age; *P. footeanum* occurs in the lower part of the Proprium Zone, probably at a level equivalent to the highest Cenomanian Scotti Zone in parts of Colorado and New Mexico; *P. paganum* occurs in the basal part of the Nigeriensis Zone just below the Cenomanian-Turonian boundary; *P. flexuosum* occurs in the lower part of the Nigeriensis Zone equivalent to a level marking the basal Turonian in west Texas and New Mexico. Successive species show an increasing whorl compression, increasingly delicate ornament and an increasing sutural complexity.

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